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CONTROLLED ENVIRONMENT EXPERIMENTS WITH PRECIS OCTAVIA CRAM. (NYMPHALIDAE)

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INTRODUCTION

"Seasonal Dimorphism" has long been of great interest to lepidopterists because the insects exhibiting this phenomenon did not conform with the early accepted principles of systematics which were based on pigmentation. Only in the early years of this century were certain previously distinct species shown to be two extreme forms of the same "seasonally dimorphic" species. This was the case with *Precis octavia* Cramer, an African butterfly. As a result of such examples, the principles of systematics were revised and based on taxonomic differences of microscopic organs instead of on pigmentation alone.

Since then, many studies have been made of the palearctic "seasonally dimorphic" species but little experimentation has been carried out on tropical species.

The tropical genus *Precis* undoubtedly exhibits the most striking differences between seasonal forms. The characters generally affected are size, wing shape (especially in tailed species) and wing colour and markings of both surfaces.

Two races of *Precis octavia* occur in Africa. The northwestern race *octavia* distributed from Sierra Leone, Congo, Ethiopia, to Somalia, and the southern race *sesamus* ranging from Angola, Kenya, Rhodesia to the Cape of South Africa. In the southern race, form *natalensis* Staudinger is predominantly red in colour on both surfaces and form *sesamus* Trimen is predominantly blue on the upperside and dark brown/black on the underside.

TABLE 1

METEOROLOGICAL DATA

KAREN, NAIROBI AREA

MONTH	Rain inches (Mean)	Temperature °C (Mean)	Max. °C (Mean)	Min. °C (Mean)	Mean Hours Sun per day	Mean % Sun per day	Relative Humidity 8.30-14.30
JANUARY	1.47	20.2	25.6	15.0	9.7	40.4	57
FEBRUARY	2.13	21.1	27.8	6.1	9.6	40.0	56
MARCH	5.27	21.1	28.9	10.0	8.3	34.6	61
APRIL	7.71	20.7	28.3	11.1	7.1	29.6	69
MAY	5.17	19.6	27.8	10.6	6.3	26.3	71
JUNE	1.62	18.0	27.8	5.6	4.5	18.8	69
JULY	0.59	17.1	25.6	5.0	4.1	17.1	68
AUGUST	0.97	17.4	25.6	4.4	4.4	18.3	67
SEPTEMBER	0.92	19.0	27.8	5.6	6.5	27.1	59
OCTOBER	1.93	20.1	27.8	7.8	7.4	30.8	61
NOVEMBER	4.02	20.0	24.4	12.2	7.2	30.0	66
DECEMBER	2.49	19.7	25.6	11.1	8.5	35.4	63
Total	34.29	19.5 Mean	:------------: 1964-1965 Karen		:----------: Kabete Met. Stn.		

:-------------------: Mean 39 years

Minimum Temperature recorded at Karen 3.9°C.

The southern race *P. octavia sesamus* is locally common in Kenya. In the Karen area, fifteen miles from Nairobi, the butterflies may be seen flying along the edges of the Ngong Forest and in the late afternoon can often be seen assembling under the eves of houses and in small stone quarries where they shelter for the night.

Larval stages occur throughout the Ngong, Karen and Kikuyu aeras of Kenya where *Coleus forskohlii,* the food plant, is used by African smallholders as a hedge plant.

The majority of butterflies seen are either of form *natalensis* or of form *sesamus.* Intermediates can sometimes be taken but these are uncommon (Butler 1901, Clarke & Dickson 1953, Pinhey 1949).

Two generations normally occur in a year. During September to November f. *sesamus* is in the majority and from January to April f. *natalensis,* but there is a normal overlap of survivors.

NATURAL ENVIRONMENTAL CONDITIONS

Although Karen is only 90 miles south of the equator, it is at an altitude of 6000 ft. and temperatures are moderate. The duration of daylight is a fairly constant 12 hours per day.

In Table 1 can be seen meteorological data for the Karen area. The information is quoted here as being typical of an area of Kenya in which *P. octavia sesamus* is found in both of its seasonal forms.

It is not at first obvious from the information on Table 1 that there is a "cold" season and a "warm" season in this area. There is little difference between the maximum temperatures for each month and also little difference between the minimum temperatures. These figures are somewhat misleading because during the period June to August, the higher temperatures are only maintained for a short time each day. During the period December to January the higher temperatures are maintained for the majority of the day and low temperatures are only achieved for very short periods. It is for this reason that I have included figures of mean daily sunlight duriation and also expressed sunlight as a percentage.

Kenya has two rainy seasons, the "short rains" during October to November, and the "long rains" of March to May. The mean monthly daytime relative humidity varies little. When one considers that the larvae feed on the flush of vegetation which occurs at the end of, and immediately after the rains, it can be seen that the late instars and pupae of the two generations ex-

TABLE 2

Precis octavia (Cram)

Parent - Wild ♀ f. natalensis (July/Aug. 1965)

Temperature °C	Humidity	Hours Light/Day	Initial No. Larvae	f. sesamus	f. miotoni	f. susani	f. nairobicus	f. transiens	f. natalensis
Uncontrolled	95	12	20	0	0	0	1	1	12
Uncontrolled	Uncontrolled	12	5	0	0	0	2	1	1
Uncontrolled	30	12	20	2	0	4	4	5	2
Parents - f. natalensis ♀ x f. natalensis ♂ (Oct.-Dec. 1965)									
32 *	30	0	20	0	0	0	0	0	0
27	30	24	20	0	0	0	0	0	13
27	95	0	40	0	0	0	0	1	19
27	30	0	20	0	0	0	0	0	8
24 ± 3	95	12	20	0	0	1	6	6	2
24 ± 3	30	12	20	0	0	1	5	2	2
21 ± 3	95	12	20	2	0	7	2	0	0
21 ± 3	Uncontrolled	0	20	3	1	1	3	5	0
21 ± 3	30	0	20	5	0	6	4	0	0
Uncontrolled	Uncontrolled	12	20	0	0	0	2	2	9

* Complete mortality resulting from extreme temperature.

perience the two differences in temperature and light intensity mentioned here.

The above information tends to rule out humidity as a factor concerned with the production of the two colour forms of this butterfly. I decided, nevertheless, to include humidity as one of the variable factors in a number of simple experiments.

EXPERIMENTAL

Towards the beginning of this century, Dorfmeister, Merrifield, Standfuss, Suffert and Weismann showed that in the family Nymphalidae, heat causes light colouration and cold causes dark colouration.

Experiments were performed on *P. octavia* by Marshall (1902) but definite conclusions were not forthcoming. Marshall suggested that the two extreme forms always alternate with each other and that intermediate forms can be produced by shock treatment or abnormal conditions. (Rothschild 1918). Clark & Dickson (1957) in their study of the life cycle of *P. octavia,* did perform experiments but reported that f. *sesamus* was not produced under the warmer conditions of Durban.

During 1965, 1966 and 1967, I reared numbers of *P. octavia sesamus* under controlled environmental conditions in three different laboratories.

Food Supply I had previously shown with English species of Pieridae and Nymphalidae that supply of food only affects the size of the imago. Prior to these experiments, larvae of *Precis archesia Cram.* and *P. octavia* were starved during their fifth instar and specimens of only 30 mm. were produced. Larvae which were given a plentiful supply of fresh food throughout their larval life produced specimens which averaged 50 mm. Consequently fresh supplies of food were provided daily in these experiments.

Light Observations on larvae in the field showed that they tend to keep to the shadier sections of their food plant and avoid strong sunlight. This is not surprising because temperatures in direct sunlight are very high in Karen. Light intensity is not likely therefore to be a factor concerned in the production of seasonal forms. However, other research workers have suggested that duration of light may play an important part in the production of seasonal forms of *Araschnia levana* L. of Europe. Despite the fact that the duration of daylight is a constant 12 hours per day throughout the year in East Africa where both extreme forms occur, I decided to include three variables of light. These were zero light, 12 hours per day, and constant light.

TABLE 3

Precis octavia (Cram)

Parents wild ♂ f. sesamus x bred ♀ f. sesamus (Sept. 1966 - Oct. 1967)

Temperature °C	Humidity	Hours Light/Day	Initial No. Larvae	f. sesamus	f. miotoni	f. susani	f. nairobicus	f. transiens	f. natalensis
30°	95	24	10	0	0	0	0	0	7
30°	30	24	10	0	0	0	0	0	5
30°	95	12	10	0	0	0	0	0	8
30°	30	0	10	0	0	0	0	0	6
27°	95	12	10	0	0	0	0	1	6
19°	95	12	20	2	1	0	0	0	0
16	95	0	10	5	0	0	0	0	0
16	30	0	10	3	0	0	0	0	0
16	Uncontrolled	0	10	6	0	0	0	0	0
5 *	95	0	10	0	0	0	0	0	0
5 *	30	0	10	0	0	0	0	0	0
Uncontrolled	Uncontrolled	12	20	14	0	2	2	0	0

* Complete mortality resulting from extreme temperature.

Temperature & Humidity Earlier experiments were performed in cabinets which lacked modern facilities. Humidity was maintained at a low level using crystals of silica gel which were replaced daily. High humidity was maintained using water bottles with cotton wool wicks. Only the higher temperatures could be maintained at a constant level using electrical heating.

Later, certain of the experiments were performed in modern constant environment rooms. Here, the control of humidity and temperature was facilitated by modern humidifying, cooling and heating equipment.

In all experiments the egg and first instar larvae were kept under moderate conditions, and larvae were introduced into more extreme conditions at the second instar. This procedure was found to greatly reduce early mortality.

Numbers of individuals reaching maturity were not as high as I intended. Mortalities from disease were often severe especially under conditions of high humidity, and on two occasions all culture insects were completely destroyed by safari ants *Dorylus nigricans* Illig. This drastically reduced the numbers of insects available for the experiments and made a properly replicated trial impossible.

RESULTS

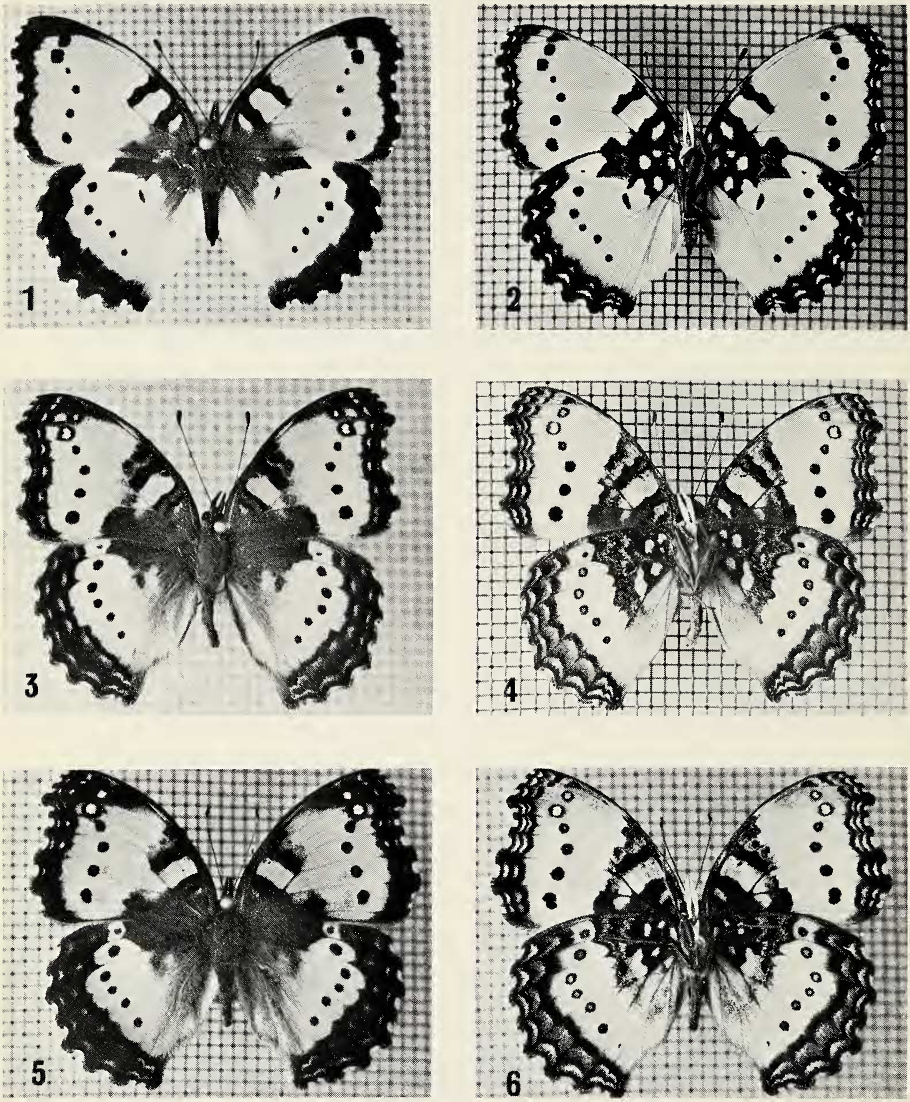
Extreme variation in pigmentation was recorded in larval, pupal and adult stages.

Throughout the experiments the majority of larvae exhibited five instars. In one instance however, several larvae in the same cage exhibited seven instars. The cage concerned was maintained at a temperature of 21°C with no humidity control and in complete darkness. The reason for the occurrence of the extra instars is not known. Clarke & Dickson (1953) also record the occurrence of five, six and seven instar larvae and suggest that it forms a mechanism for staggering emergence of adults.

Head capsules were collected anl mounted from each cage and these completely verify the observations.

Pigmentation of Larvae

Early instars did not vary their pigmentation according to the differing environmental conditions. It soon became apparent that the colour of the fifth instar larvae varied according to temperature. At the lower temperatures the larvae were black and at the higher temperatures they were orange, without exception. The larvae which exhibited seven instars showed variations in pigmentation in the seventh instar only.



Figs. 1-6 *Precis octavia* Cram.
Upperside, left; underside, right. 1 and 2, f. *natalensis* Staudinger ♂; 3 and 4, f. *transiens* Wichgraf ♂; 5 and 6, f. *transiens* Wichgraf ♂.

The situation was further complicated by the discovery that there were two strains of larvae which exhibited different colour forms. The earlier experiments of 1965 (Table 2) produced all "plain" larvae and the experiments of 1966-67 (Table 3) produced a mixture of "plain" and "striped" larvae. The appearance of a second type of larva in the second series of experiments corresponded with the introduction of another strain of adult (derived from the same locality).

The two types of larvae and the way in which the pigmentation of the final instars is changed with temperature, are described here.

Plain Larvae — Final Instar

21°C. and below

Almost entirely velvety black with metallic blue bases to the spines. Two yellowish patches occur in each thoracic segment, situated one on each side of the mid-dorsal line. These patches may be absent at low temperatures.

24°C.

As above but the yellowish patches extend the entire length of the larva along the mid-dorsal line and the lateral ridge.

27-32°C.

Larvae entirely orange-yellow with areas of red at the bases of black spines.

Striped Larvae Final Instar

21°C. and below

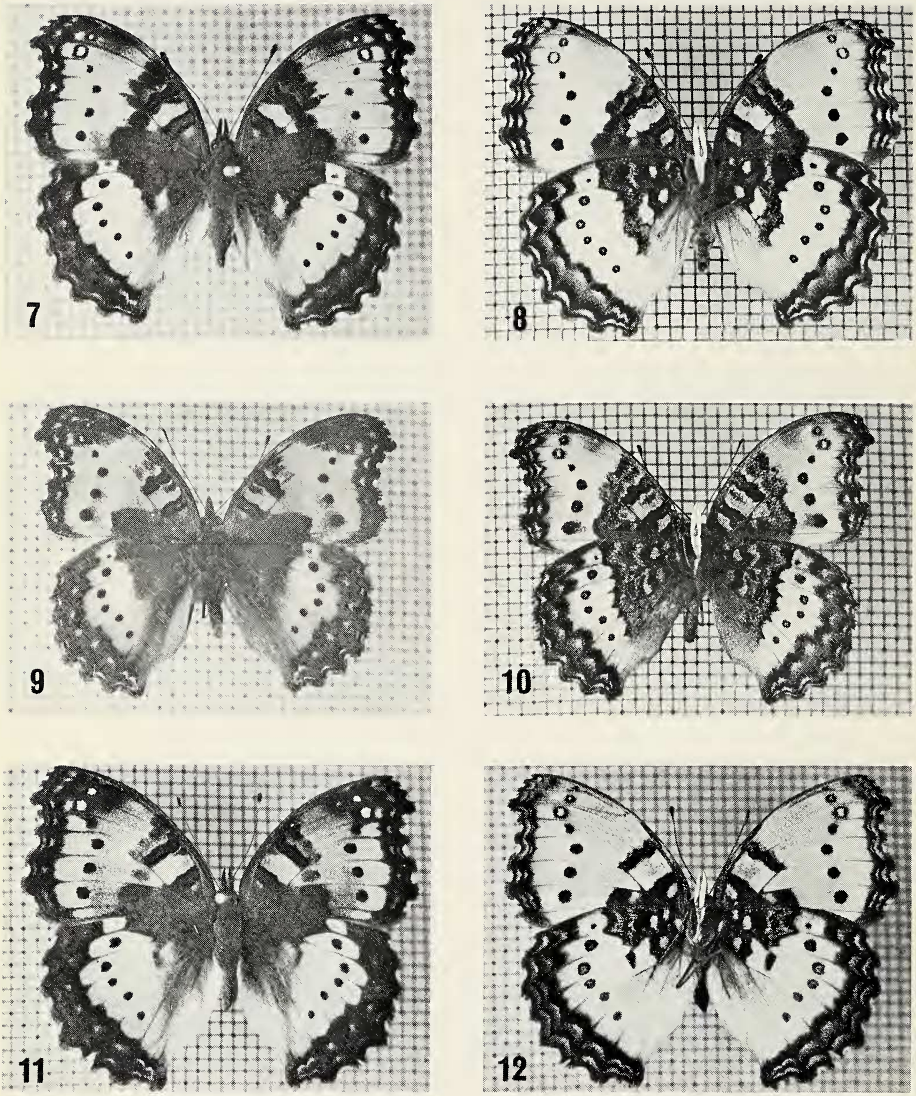
Ground colour black broken in each abdominal segment by stripes of yellow which pass from the mid-dorsal line down to the laterial ridge. Two of the yellow stripes are narrow and positioned adjacent to the intersegmental membranes, i.e. they are positioned at the anterior and posterior of each segment. The third yellow stripe is broader and positioned slightly anterior to the centre of each segment. As in the plain larvae, these also have yellow patches dorsally situated in the thoracic segments.

24°C.

The black areas become slightly tinted with orange especially the areas adjacent to the mid-dorsal line and lateral ridge.

27-32°C.

The black areas become entirely orange-red in colour.



Figs. 7-12. *Precis octavia* Cram.
Upperside, left; underside, right. 7 and 8, f. *transiens* Wichgraf ♀; 9 and 10, f. *transiens* Wichgraf ♂; 11 and 12, f. *nairobicus* (f. nov.) ♂ Paratype.

Pigmentation of Pupae

Pupae occurred in four different colour forms which were in no way related to colour forms of larvae or adults. Also they did not correspond with any of the environmenal factors or background colour of their cages. The four colour forms were dark brown, light brown, mottled and gold.
(Colour Plate 1, Fig. 4)

Pigmentation of Adults

Results obtained are summarised in Tables 2 and 3. These indicate that neither the light duration nor humidity affect the pigmentation of the adult. Temperature changes almost exactly correspond to the differences in pigmentation of the adults. At the higher temperatures, 27-32°C. f. *natalensis* was produced, and at the lower temperatures, 10-16°C. f. *sesamus* was produced irrespective of the form of the parent or sex of the individual.

A complete range of intermediate forms was bred at temperatures between 18-24°C. A selection of these is illustrated here in Figures 3-26. Some of these intermediate forms do not correspond with the description of f. *transiens* (Wichgraf 1918). I therefore make descriptive notes here on three new forms as well as the three forms already described.

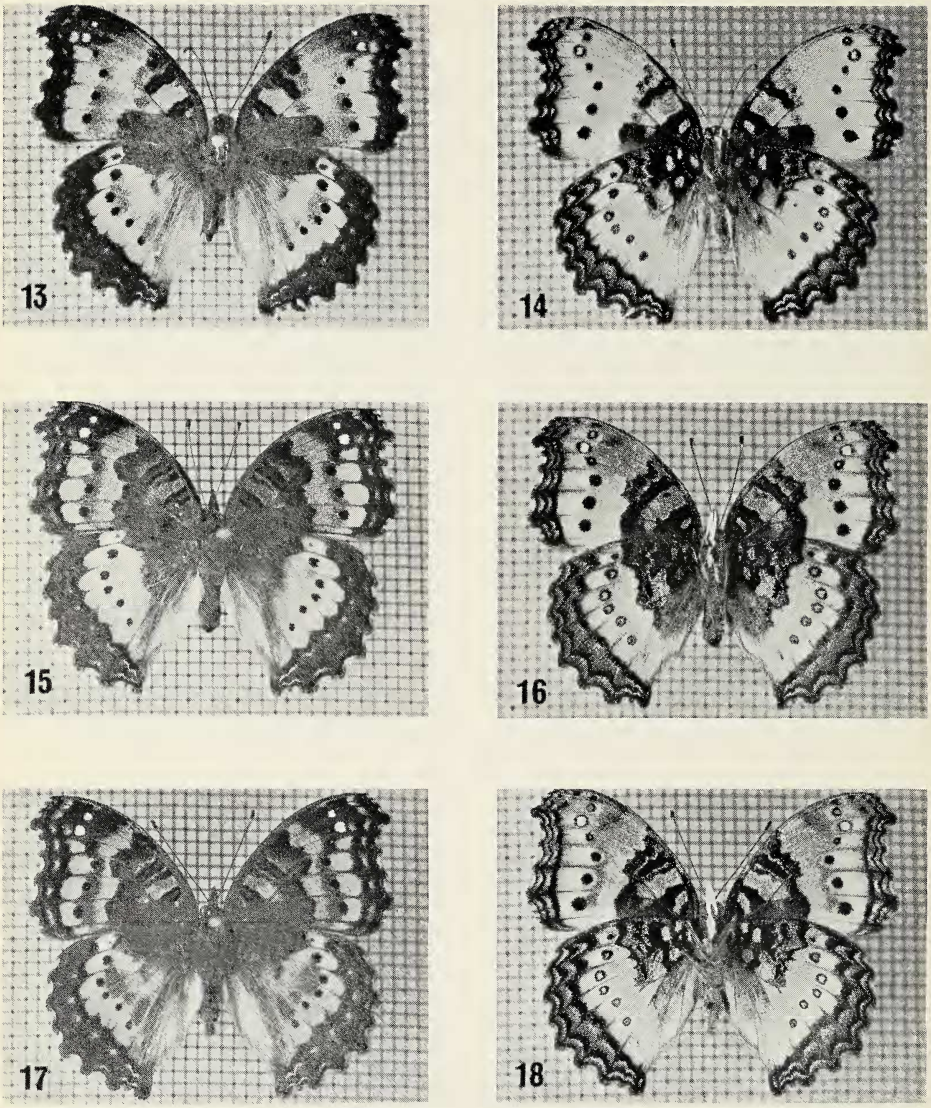
Many lepidopterists feel that separate names should not be given to temperature forms. In this case I feel that because of the extreme differences within this species, the various forms should be named and described for ease of reference.

DESCRIPTIVE

1. *f. natalensis* Staudinger (Figs. 1-2)

Upperside. Ground colour strongly red with a black margin along the outer border. All discal spots are black and do not possess pupils. Those of cellules 5 and 6 are larger. No blue scales are present on the proximal side of the discal spots. A dark brown area passes from the base of the forewing to half way along the inner margin and connects with the first transverse bar of the cell but not the second.

Underside. Black areas occur at the bases of all wings. These black areas contain four orange patches on the hindwings. Ground colour pinkish red and wings are not demarcated into halves.



Figs. 13-18. *Precis octavia* Cram.
Upperside, left; underside, right. 13 and 14, f. *nairobicus* (f. nov.) Holotype ♂; 15 and 16, f. *susani* (f. nov.) Paratype ♀; 17 and 18, f. *susani* (f. nov.) Holotype ♂.

Note. Some specimens at first sight appear to be of f. *natalensis* but possess blue or more rarely white pupils to the discal spots of cellules 5 and 6. It will be found on close examination with a lens that blue scales are present on the proximal side of discal spots of cellules 1 and 2 of the forewing. These specimens are therefore of *f. transiens* Wichgraf. Generally all specimens with blue or white pupils to discal spots in cellules 5 and 6 are intermediates or *f. sesamus*.

2. *f. transiens* Wichgraf (Figs. 3-10)

Upperside. Ground colour red with a black margin along outer border. Small areas of blue scales occur on the proximal side of the discal spots in cellules 1 and 2 only of the forewing. Discal spots of cellules 5 and 6 of the forewing with white or blue pupils. Dark brown areas occur on the distal side of the second transverse bar of the cell of the forewing and these may or may not connect up with those of the inner margin.

Underside. Basal half of each wing tends to be demarcated from the distal half, and is dark brown/black in colour compared with the pink/red of the distal half. Marginal band broad with two rows of blue streaks on upperside and underside.

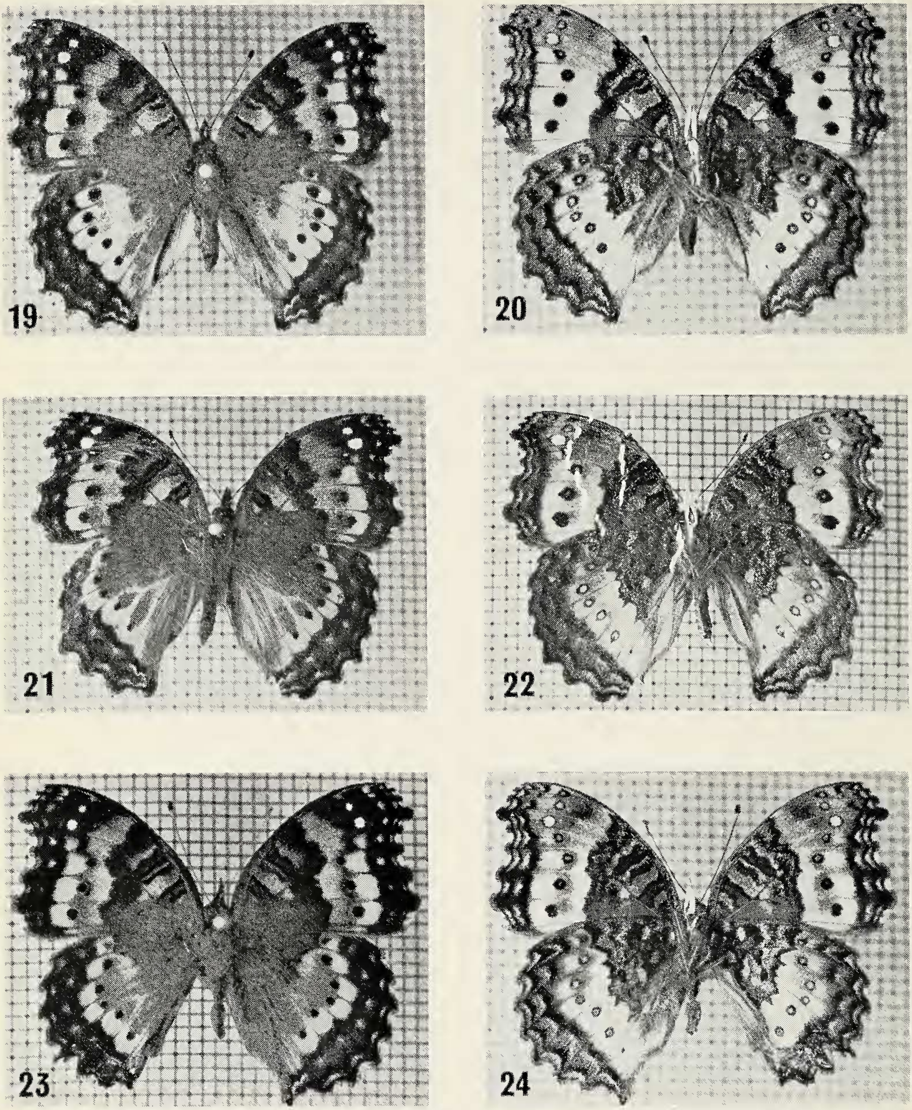
3. *f. nairobicus.* f. nov. Holotype ♂ Allotype ♀
Bred from wild-caught ♀ Karen, Nairobi, Kenya.
Paratypes 9 ♂ 5 ♀, as Holotype and Allotype, in author's collection.

Upperside. As in f. *transiens* but blue areas occur on the proximal side of all the discal spots of the forewing and may also occur on the hindwing. These blue areas remain separate in each cellule and do not join together. Discal spots in cellules 5 and 6 of the forewing possess white pupils .

Underside. As in f. *transiens*.

4. f. *susani* f. nov. (Figs. 15-24)
Holotype ♂
Allotype ♀ Bred from wild-caught ♀ Karen, Nairobi, Kenya
Paratypes — 10 ♂ 7 ♀ as Holotype and Allotype, in author's collection.

Upperside. Ground colour red. Blue areas are present on the proximal side of all discal spots of the forewings and hindwing. In the forewings the blue areas in cellules 1-6 join together to form a bar. In the hindwings the blue areas tend to be oval and separate in each cellule, but in more extreme forms the blue areas unite here also. The areas of dark brown positioned dis-



Figs. 19-24. *Precis octavia* Cram.
Upperside, left; underside, right. 19 and 20, f. *susani* (f. nov.) Allotype ♀. 21 and 22, f. *susani* (f. nov.) Paratype ♂; 23 and 24, f. *susani* (f. nov.) Paratype ♂.

tally to the second transverse bar of the cell of the forewing, join up with those running along the inner margin from the base.

Underside. Basal half of all wings sharply defined and bounded by a curved dentate line. The distal halves remain pinkish red in colour but the basal halves are dark brown/black.

5. *f. miotoni* f. nov. (Figs. 26-26)
Holotype ♂ In author's collection.
Paratype 1 ♂ Both bred from insects wild — caught in Karen, Nairobi, Kenya. Obviously intermediate between f. sesamus and f. susani but the areas of blue scales on the proximal side of the discal spots are diffused amongst the red scales instead of occurring in definite areas. This results in an overall lilac appearance. The area discal to the discal spots of cellules 1-4 remains red traversed by the dark veins 2-4. Discal spots in cellules 5 and 6 of the forewings possess white pupils.

6. *f. sesamus* Trimen (Figs. 27-28)

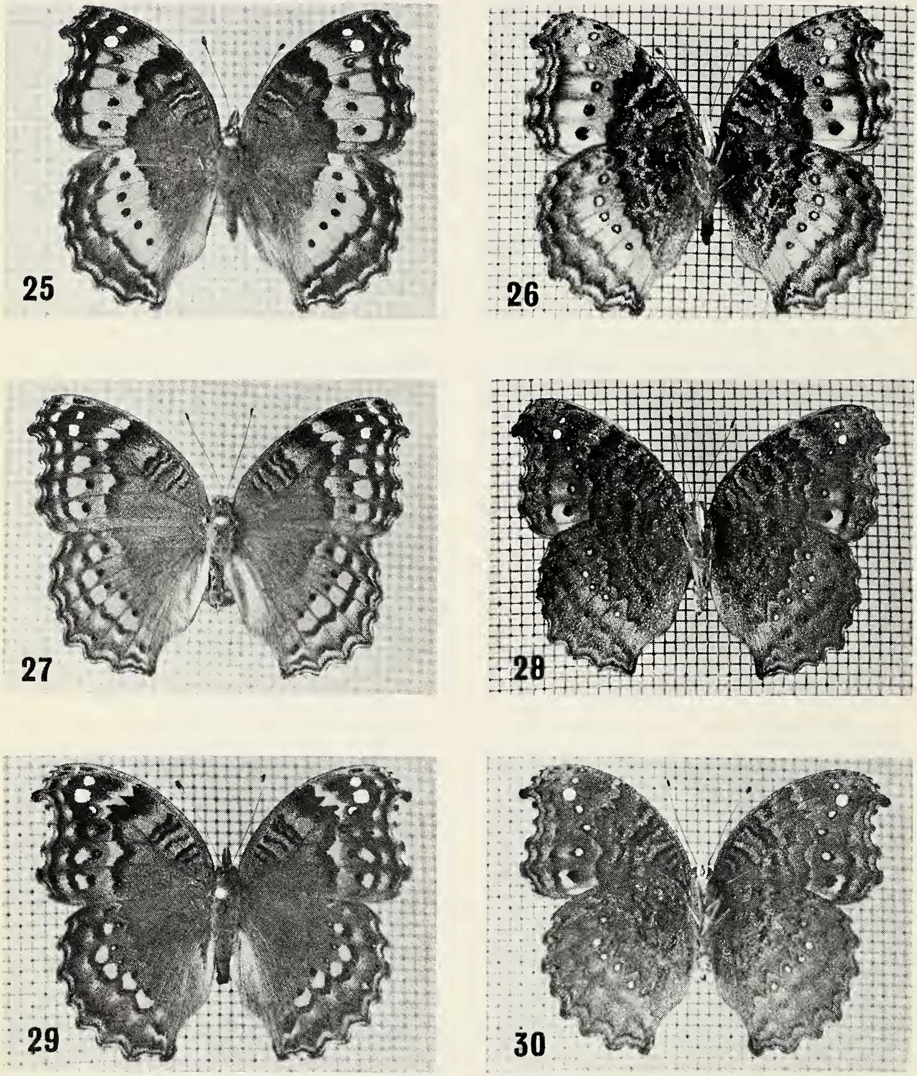
Upperside. Ground colour blue with a tendency to purple. Forewings project slightly at the extremity of vein 6. Discal spots in cellules 1-4 black, in cellules 5-6 white pupilled. Distal to the submarginal spots of cellules 1-4 are four large red spots. Marginal band broad with two rows of blue streaks. Basal half of all wings dark brown.

Underside. Ground colour dark brown/black with perhaps traces of pinkish red in cellules 2-3. The basal half of each wing is bounded by a curved dentate line. Discal spots in cellules 5-6 possess white pupils. Discal spots in cellules 1-4 with or without white pupils. Note. In extreme forms the discal spot in cellule 4 of the upperside of the forewing also has a white pupil (Fig. 29) and lines are more dentate especially those demarcating the basal from the distal halves of the wings. The forewings project at the extremity of vein 6 and the ground colour is more of a definite blue.

SUMMARY & CONCLUSIONS

A brief distribution of *Precis octavia sesamus* in Africa is given. Meteorological data is quoted for an area of Kenya in which both extreme forms of the butterfly occur. Previous studies of this species are mentioned.

Experiments are outlined in which numbers of *Precis octavia sesamus* were reared under controlled environmental conditions. The environmental factors controlled were humidity, light dur-



Figs. 25-30. *Precis octavia* Cram.
Upperside, left; underside, right. 25 and 26, f. *miotoni* (f. nov.) Holotype ♂; 27 and 28, f. *sesamus* Trimen ♂; 29 and 30, f. *sesamus* Trimen ♀.

ation and temperature. (Food supply had previously been shown to be unrelated to pigment changes.

Although numbers of insects were not large, the author considers the evidence sufficient to conclude that:

a) The only environmental factor to affect the pigmentation of *P. ovtavia sesamus* is temperature.

b) Temperature, as well as controlling the pigmentation of the imago, also controls the pigmentation of the final instar larva.

c) The pigmentation of the pupa is unrelated to temperature.

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EDITOR'S NOTE: It is planned at some time in the near future to illustrate the larvae, pupae and adult forms in color.